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ABSTRACT

Two experiments were conducted to test three hypotheses related to comprehension. The hypotheses were: that actions are harder to modify than states; that implications or inferences from modified concepts would also change in memory; and that propagation of modifications would be less likely to states than to actions. The first experiment tested the direct modifiability of actions versus states and the propagation of modifications from actions to states versus modifications from states to actions. Results indicated states are initially easier to modify than actions. Propagation of modification through memory occurs, especially from states to related actions. In the second experiment, all possible pairs of actions and states were filled out. The demands on the subjects' processing were increased in several ways. Results indicated propagation of misleading information from states to related actions and, less strongly, from actions to related states. The least propagation occurred to related states. States were not typically inferred. The experiments confirmed the hypothesis that question answering is an integrated memory search update process, and representation of narratives is "action oriented." Further systematic study should be conducted to determine how questions and memory interact. This knowledge would provide educators with a more effective teaching tool. (DWH)

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Alterations in Memory for Text by Leading Questions

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Elizabth Loftus' (1979) experiments on misleading questions have demonstrated very conclusively that subjects' memories can be changed after they hear a question containing a misleading presupposition. An example of such a question is: "How fast was the car going when it ran through the stop sign?," where the car actually ran through a yield sign. Subjects in Loftus' experiments answered questions like the stop-sign question after seeing a sequence of slides depicting events like a car running through a yield sign. When asked later about what kind of sign was at the intersection, many subjects remembered seeing a stop sign. Their memory had become consistent with the information contained in the question presupposition.

This phenomenon has important legal ramifications concerning the efficacy of eyewitness testimony, but why should we be talking about it here? The reason is that to account for the modification of memory by question presuppositions requires a model of language understanding, and question answering in particular, in which comprehension and memory are closely related. It is traditional to think of question answering as involving two steps: 1) parsing of the question, and 2) use of the parsed question as a key to memory search and retrieval (Winograd, 1972; Woods, 1978; Lehnert, 1978). We would like to argue instead for a more integrated view in which the representation of whatever is being asked about effects the understanding of a question, and in which the understanding of the question affects the representation of whatever is being asked about (Dyer, 1981). In this talk, we will address the latter question only.

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We would like to argue that the comprehension processes involved in understanding a question are no different than those involved in comprehending a new statement except that a reply is output after comprehension. This is reasonably demonstrated by the following sentence with two possible sentences after it:

(1) John and Bill met at a restaurant to discuss a deal.

(2a) During lunch they were joined by a friend.

(2b) Why did John and Bill meet for lunch?

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The new information in both of the second sentences--namely that John and Bill had lunch--should be added to the memory representation regardless of which statement was uttered. We would be suprised if

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someone failed to remember whether John and Bill had lunch or dinner after being asked 2b. Thus, comprehension and question answering should behave the same way.

Following all this out, we would expect that processes that we know about in human memory for stories should apply to memory modification of stories by leading questions. In the experiments I am going to describe, we tested whether a familiar memory phenomenon--that actions in narratives are remembered better than states and are thus represented more centrally or strongly in memory (Black, 1980; Graesser, Robertson, Higgenbotham, and Smith, 1978; Graesser, Robertson, Lovelace, and Swinehart, 1980)--carries over to affect memory modification. Specifically, from the results just mentioned we expect actions to be more difficult to modify than states.

Additionally, we know that the generation of inferences is an important aspect of normal comprehension and so we would expect to see inferencing from new information which was added by misleading questions. Does modification of one portion of a representation propogate through conceptual links and change other portions of the representation? Also of interest is whether some types of inferences are more likely to occur than others. In related research (Seifert, Robertson, & Black, Note 1) we have hypothesized that (all other things being equal) inferences about states are less likely to be made during comprehension than inferences about actions. Part of the reason for this is that states can be easily inferred at a later time from knowledge of actions and thus need not be explicitly represented. If this is true, then propogation of memory modifications to connected states should be less likely than propogation to connected actions.

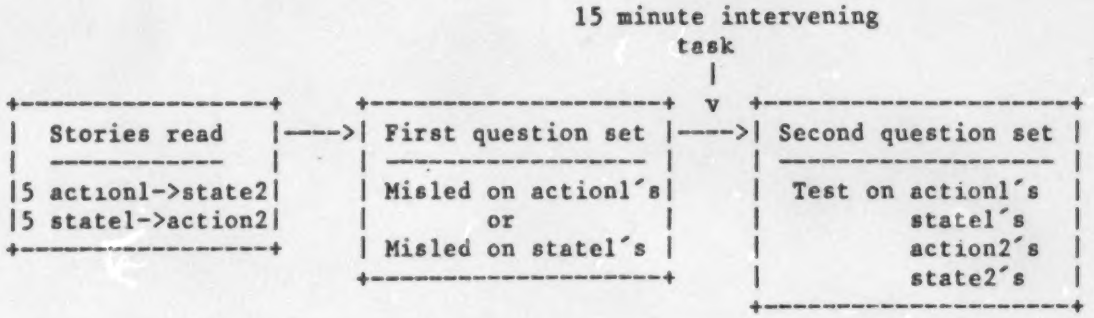
To test these three hypotheses--that actions are harder to modify than states, that implications or inferences from modified concepts would also change in memory, and that propogation of modifications would be less likely to states than to actions--we conducted two related experiments. The first experiment tests the direct modifiability of actions versus states and the propogation of modifications from actions to states versus from states to actions. The second experiment replicates the direct modification findings of the first and tests propogation effects in a more detailed manner. We will look at each experiment in turn.

In the first experiment, we wrote five stories containing an action-state pair and a state-action pair. In each pair, the action and state were related to each other in such a way that knowledge about one would determine what was known about the other. So, for example, one item we used was about a man who opened a window in his office because a vistor in the office was warm. Opening the window is an action and the visitor's warmness is a state. Opening the window and being warm are causally connected--if we thought that the office window had been closed, for example, then it should also be the case that the visitor was cold, not warm. In the action-state pairs an action led to a state and in the state-action pairs a state led to an action.

Twenty-four subjects read the stories and then answered a number of questions about them. Some of the questions contained a misleading presupposition about the initial state or action and some were neutral. An example of a misleading question about the window action is "What did A ask B after A closed the window?," an example of a neutral question is "What did A ask B after A adjusted the window?." There were no misleading questions about the second part of the action-state and state-action pairs.

After answering the first set of questions the subjects were engaged in a short intervening task. They then answered a second set of test questions. In the test questions they were asked about both the initial states or actions and the connected, second portion of each pair. A graphic representation of the paradigm might be helpful at this point (Figure 1):

Figure 1. Graphic representation of the design used in Experiment 1.



We were interested in showing a difference in the modifiability of the initial actions versus the initial states, and we wanted to see if the modification of an initial item would lead to the modification of a connected secondary item.

Subjects' answers to the test questions were scored on whether they corresponded to the misleading presuppositions of the questions or to the original story. A subject's probability of answering according to the misleading presupposition when asked a misleading question minus his or her probability of answering according to the misleading presupposition when asked a neutral question (answering wrong even though not misled) was calculated for the initial actions and states and for the secondary actions and states. This measure is referred to as a "misleading difference score." A similar measure was calculated for subjects' probabilities of answering "I don't know" or other indications of confusion. This measure is referred to as a "confusion difference score." These measures tell us the proportion of times that subjects answered as if they were misled or confused over and above a baserate for normal mistakes or confusions.

Table 1. Mean misleading difference scores and confusion difference scores for initial states and actions and secondary states and actions.

Misleading difference scores			Confusion difference scores		
Initial Item Type	Initial	Secondary	Initial Item Type	Initial	Secondary
State	.19	.08	State	.14	-.08
Action	.05	.06	Action	.03	.15

Table 1 shows the mean misleading difference scores and confusion difference scores for initial actions and states and for secondary actions and states (remember that the secondary actions are connected to initial states and secondary states are connected to initial actions). It is clear from this table that initial states were more susceptable to direct modification than initial actions. It is also apparent that there was some spreading of the of modification from initial states to connected secondary actions and that this spreading resulted in confusion about the connected actions. There is no evidence from this data for spreading of misled information from initial actions to their connected states, but the small amount of initial misleading on actions may be responsible for this lack of an effect. (Note: A second factor, order of the test questions about initial and secondary items, was varied to assess any differential effects that answering a question about an initial item might have on answering a later question about its connected item. There were no effects of question order.)

Conditional probabilities will give us a more democratic look at any propogation effects in this data. Table 2 shows the conditional probabilities of secondary items being judged misled and not misled in cases where the initial items were misled and not misled. From this data we see that the probability of an initial state modification leading to a secondary action modification was very high and that there were no cases in which a secondary action modification occurred without an initial state modification. Also we see that the probability of a secondary state modification was much higher when the initial action was modified than when it was not.

Table 2. Conditional probabilities of secondary item modifications given modification of the initial items and no modification of the initial items.

Given	Probability of: Secondary Action Modification	Probability of: No Secondary Action Modification
Initial State Modification	.73	.27
No Initial State Modification	0	1.00

Given	Probability of: Secondary State Modification	Probability of: No Secondary State Modification
Initial Action Modification	.50	.50
No Initial Action Modification	.02	.98

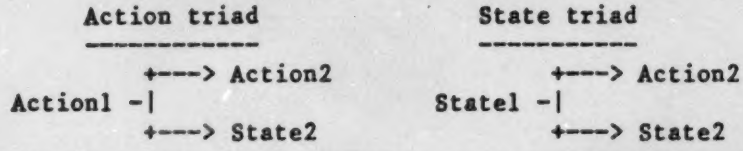
Thus the first experiment gives evidence that states are initially easier to modify than actions and that propogation of modifications through memory occurs, especially from states to related actions and less reliably from actions to related states.

In a second experiment we decided to fill out all possible pairs of actions and states, that is action->state, action->action, state->action and state->state. We also increased the demands on subjects' processing in a number of ways. First, they were given a 3300 word story to read. They were then asked a large number of questions (75) about the story and they were given intervening tasks between story reading and questioning and again between questioning and testing. The first task took 15-20 minutes, the second 30-35 minutes, so that it was typically 1 1/2 hours between the time the story was read and the time of testing. A recognition test was used to measure memory for the story items.

There were 24 critical items in the story. Each item consisted of an initial action or state and both a secondary action and a secondary state. Thus the items were triads like those pictured in

Figure 2. Twelve of the items were action triads (initial action) and twelve were state triads (initial state).

Figure 2. Schemata for the items in Experiment 2.



An example of a state triad is the following:

State1: It was too warm to write in the office.
Action2: She opened a window.
State2: There was a cool breeze now and she felt better.

With these items, it was possible to mislead on any portion of the triad--action1, state1, action2, or state2--and measure the effects on that portion plus any effects on other portions of the triad. In fact, each subject was misled on a different part of each item triad and wound up being misled twice on each part (i.e. Each subject was misled on two action1's, two state1's, two action2's in state triads, two action2's in action triads, etc.). Each subject was misled on six of the action triads (different parts) and six of the state triads (different parts). On the other twelve item triads, subjects were asked neutral questions as in the first experiment. Over subjects, each part of each item triad wound up being misled about and having a neutral question asked about it.

At this point, twelve subjects have been run through this harrowing design. At test time, the subjects were given a recognition test containing recognition items about all 3 parts of each item triad. They used a 1-7 scale on which 7 meant that the item was "definitely true" of something they had read in the story and 1 was "definitely not true" of something they had read. Each subject saw True recognition items for half of the triads and False recognition items for half of the triads. Half of the Trues had been misled about and half had not. Similarly, half of the Falses had been misled about and half had not.

While there are many combinations we could look at in this data, we will concentrate here on a comparison of the action1 items and state1 items and a comparison of the four possible ways that misleadings could spread, namely from the action1 portion of a triad to its action2 and state2 portions and from the state1 portion of a triad to its action2 and state2 portions.

The measure of interest here is the mean recognition score given to not-misled items minus the mean recognition score given to misled items. For Trues, a high "misleading difference score" indicates more misleading because the recognition of True items should go down when

they are misled. For Falses, a low "misleading difference score" indicates more misleading because the recognition of False items should go up when they are misled. Taking the difference between Trues and Falses provides a "discrimination score" which is higher the more misled subjects are (the higher the Trues and the lower the Falses).

Table 3. Mean misleading difference scores and dicrimination scores for initial actions and initial states.

Initial Item	True	False	Disc.
Action1	1.17	- .25	1.41
State1	1.25	-1.33	2.58

Table 3 shows the mean misleading difference scores and discrimination scores for initial actions and initial states. The discrimination scores show that, as in Experiment 1, the states were more easily modified than the actions. Being misled tended to lower the mean True rating for both actions and states; misled state Trues being lowered only slightly more than misled action Trues. The subjects, however, were much more likely to false alarm to a misled state than to a misled action. In fact, they did not seem to be false alarming to misled actions at all. This data reiterates the finding that states are easier to mislead than actions and gives some evidence that the misled memory trace of a state is incorporated into memory in a strong enough fashion to produce false alarms.

Some items, of course, were more easily modified than others, and the data in Table 3 is combined over both items which were difficult to modify and items which were easy to modify. If we categorize the 12 action items and 12 state items according how easy they were to modify, will there be more state items in the modifiable category and will the mean discrimination score of modifiable state items be greater than the mean discrimination score of modifiable action items? In general, a positive discrimination score indicates that an item was misled. How large we should require the score to be before we categorize an item as misled is a difficult question, but our weakest test would be to call scores greater than 1.0 misled and scores less than or equal to 1.0 not misled. Table 4 shows the distribution of items and the mean discrimination scores for both initial actions and initial states in the modified and not modified categories using 1.0 as a criterion value.

Table 4. Distibution of initial action and state items and mean discrimination scores in Modified (discrim. score greater than 1.0) and Not Modified categories.

Initial Item	Modified	Not Modified	Mean
Action1	3.38 (8)	-2.50 (4)	1.41 (12)
State1	6.14 (7)	-2.40 (5)	2.58 (12)

While there are not more state items than action items in the modified category, the degree of misleading for modified state items is almost twice that of action items. Again, states prove to be more modifiable than actions. Higher criterion values lead to a greater advantage for states over actions in terms of the distibution of items in the two modifiability categories. Table 5 shows the number of items which fall into the modified category if we use discrimination scores greater than 1 as the criterion value above which we judge an item to be misled. This table shows that there are consistently more states than actions which fall into the modified category as we use higher criterion values.

Finally, we will look again at the propogation effects of misleading questions by looking at the mean discrimination scores for secondary items--action2's and state2's--in cases where the initial state or action was misled versus when it was not misled. Figure 3 shows the mean discrimination scores for secondary items associated with each of the initial items when they were judged misled versus when they were judged not-misled.

Table 5. The number initial states and actions (out of 24 altogether) which fall into the "Modified" category as the criterion discrimination score is increased.

Initial Item	Criterion for misled jugement									
	1	2	3	4	5	6	7	8	9	10
Action1	8	4	2	2	1	1	1	0	0	0
State1	7	7	6	6	3	2	2	2	1	0

Figure 3. Mean secondary discrimination scores associated with modified primary items and with not-modified primary items. Key: SA = state1->action2, SS = state1->state2, AS = action1->state2, AA = action1->action2.

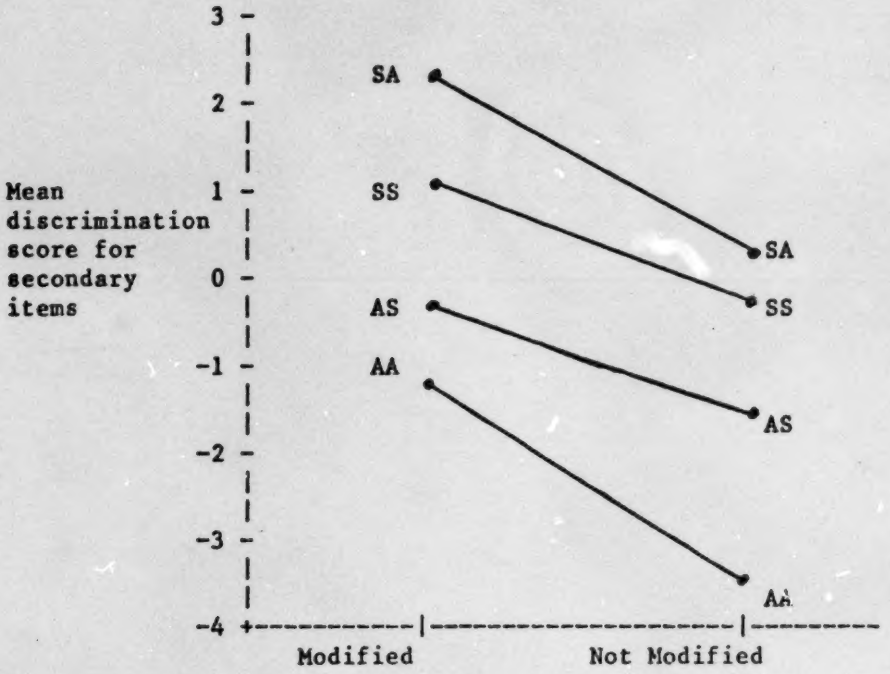


Figure 3 shows that some propogation is apparent for all pairs. The weakest effects seem to be for propogations from states to other states which is what we would expect from a comprehension model in which states play a less important role. The most pronounced propogation is from initial actions to secondary actions, again what we would expect from a model in which actions play a more central role. As in experiment 1, we again observe propogation of misleading information from states to related actions and, less strongly, from actions to related states. The least propogation seems to be to related states. This result is consistent with the view that states are not typically inferred.

These experiments show that question answering in the context of narrative comprehension can have effects on the representation of a text in memory. These effects are what would be expected if the question answering process was much like the process of normal comprehension. In particular, just as actions are typically better remembered in narratives than states, they are more difficult to modify by presentation of a misleading question presupposition. This

finding lends support to the view that the representation of narratives is "action oriented" on the one hand, and tends to confirm the hypothesis that question answering is an integrated memory search-upate process on the other.

Additionally, evidence was provided that a change in one portion of a memory representation can propogate along conceptual links and modify other portions of the representation. This seems to be the case especially for propogation to connected actions, although propogation of other kinds was observed as well. This result again lends support to theories of inference generation during understanding and, at the same time, supports an integrated model of question answering.

That it is possible to influence what people know by careful use of questions has been known since the time of Socrates. However, since not all questions are as likely to influence memory as others, and since some kinds of questions are likely to lead to more extensive influences than others, it makes sense to study systematically how questions and memory interact. An educator with knowledge of how best to ask questions that influence memory will be armed with a more effective teaching tool than one who lacks such knowledge.